GUIDELINES FOR WRITING A SCIENTIFIC REPORT

*The first section of a scientific report should focus on the research question and experimental design. This part of the report (**research design**) should be structured to include the following components:*

Research Question:

This is a focused question providing concise details about the scope of the study (either experiment, fieldwork or database analysis). It should contain reference to both the dependent and independent variables, as well as incorporate other key conditions that are required to establish the specifics of the system in which the research question is embedded (e.g. timings, concentrations, volumes, etc.).

Introduction / Background:

This section functions to outline the key information required to understand the context and purpose of the investigative study. This involves defining key terms and explaining relevant biological concepts. It also allows a candidate to contextualise the investigation by explaining the application of the study and its relevance to the wider community.

Hypothesis:

A hypothesis is a prediction of the expected experimental results. It is always framed as a statement (it is not a question). Including a hypothesis ensures that a conclusion can always be made from the data generated (a hypothesis is either supported or rejected by the data obtained). It is also important that a justification is provided linking to existing scientific theory that was outlined in the introduction.

Variables:

This section identifies the different variables which are either manipulated or controlled in the design:

- The independent variable is the specific condition that is being manipulated within the experiment
- The dependent variable is the condition which is being measured within the experimental design
- Controlled variables include the conditions which are kept constant to avoid extraneous impacts
- Uncontrolled variables include the factors that cannot be kept constant and may confound results

Materials:

This section lists all the equipment and consumables used within the experiment. Quantities should reflect the amounts needed to complete all repetitions (not just one trial). Uncertainties associated with measuring equipment or the calibration errors for devices should also be included in this section.

Methodology:

The method is a list of numbered steps that outline the process by which experimental conditions are established and how relevant data is collected. The method should contain sufficient information to allow for the design to be independently replicated, while avoiding repetitive information. The method must include an appropriate number of replicates or repetitions to allow for the collection of sufficient data for processing. It may be divided into sections for ease of communication. If a pilot study was conducted, it should be included as a separate section before the method *(procedural development)*. Relevant safety precautions and ethical considerations can be outlined in a separate section after the method. For ecological studies, the potential environmental impact of the study should be assessed.

*The second section of a scientific report should focus on data collection and statistical processing. This part of the report (**data analysis**) should be structured to include the following components:*

Raw Data:

Both qualitative data and quantitative data should be presented within the results section of a report.

Qualitative data will include written observations for each experimental condition, with specific mention made of all trials that exhibit unusual activity (this information can be used to support trends and identify any outliers). Labelled pictures may also be included to illustrate any observations made.

Quantitative data should be presented in a single table that includes all repetitions for each condition. Any outliers should be highlighted (in bold) and excluded from any subsequent statistical processing. An explanation for any outliers must be included within the report in order to justify their removal.

Processed Data:

Processed data should be included in a separate table with formulae and sample calculations shown underneath. Measures of central tendency and spread should be included. A test of skewness can be employed – use mean and standard deviation if the data is normally distributed, while the median and interquartile ranges may be used if the data is skewed. Percentage uncertainty may also be calculated for each experimental condition to allow for an assessment of the accuracy of data. Upper and lower boundaries may be included to support the determination of any outliers within the data.

Graph:

The processed data must be presented in a graphical display to support the determination of trends and patterns. Axes must be appropriately labelled, while error bars should be included for each data set to show the variation between repetitions. Scatter plots are used when the data is continuous, while bar charts are more appropriate when the data is discrete (e.g. nominal categories). If a scatter plot is used, a trend line should be included (do *not* connect the dots).

Statistical Analysis:

A range of different statistical measures can be employed based on the way the data is presented. If a trend line is used, then the significance of the trend can be determined via regression analysis. For a linear trend line, a correlation coefficient may be determined (r value). A value close to 1 is considered a strong correlation, while a value closer to 0 indicates no correlation. If the trend line is non-linear, a coefficient of determination (r^2 value) is used to determine how well the data fits the generated trend.

Further testing should be utilised to determine if the differences between the data sets is statistically significant. If a linear trendline has been established, then multiple t-tests may be used to compare the significance of the experimental groups against a baseline control group. If the generated trendline is not linear, an ANOVA test may be used to determine if there is any difference between the groups, and if so, a post-hoc test (Tukey's HSD) may be conducted to determine which of the sets of data are significantly different from each other. The results of a statistical test are considered significant if the test generates a value that exceeds a critical threshold representing a 5% probability that the results were due to chance (i.e. $p<0.05$). A critical value varies depending on sample size (degree of freedom). If the value generated exceeds the critical threshold, an alternative hypothesis is accepted (indicating that there *is* a significant difference between the groups). If the value generated falls below the critical threshold, then the null hypothesis is accepted (there is *no* significant difference between groups).

*The third section of a scientific report involves interpretating the processed data to form conclusions. This part of the report (**conclusion**) should be structured to include the following components:*

Discussion:

There are three main things to cover in the discussion section. Firstly, a candidate should summarise the experimental results, describing any patterns or trends. Qualitative observations can be used to provide evidence supportive of the numerical data. If no clear trend exists, this will need to be stated.

The second thing to do is to analyse the reliability of the data. This involves an evaluation of both the accuracy of the data (based on percentage uncertainties) and precision (based on standard deviation and error bars). Any anomalous data points (i.e. outliers) need to be identified and the significance of any trends discussed (based on correlation coefficients and other statistical measures like the t-test).

The final thing to do in this section is to provide a scientific explanation for the generated data. This will involve comparing the established results to the relevant concepts identified in the background literature (previously cited in the introduction) and providing a justified interpretation for any trends. Attempts should also be made to explain any unexpected or irregular patterns present within the data.

*The final section of a scientific report involves an assessment of the design for methodological flaws. This part of the report (**evaluation**) should be structured to include the following components:*

Evaluation:

In this section, both weaknesses and limitations should be identified and discussed. A weakness is a procedural flaw that could potentially impact the data collected, while limitations are methodological restrictions that reduce the applicability of the findings. Weaknesses should be discussed in terms of their impact on the experimental results. A weakness will be considered generic if it is not expected to have a meaningful effect on the collection or quality of the data. A reasonable improvement must also be suggested for each weakness (one that could be incorporated into the experimental design without excessive expense or access to unrealistic equipment). Future experiments should also be suggested to address each identified limitation.

Conclusion:

A conclusion should be a brief statement that succinctly summarises the outcome of the experiment, addressing both the hypothesis and research question. The conclusion should cite evidence from the results (outlined in the discussion) and balance this against any weaknesses in the design (described in the evaluation). A conclusion will function to determine the overall validity of the experimental data.

References:

Appropriate referencing of all sourced information used in the report of the scientific investigation is expected. The omission of sources or improper referencing will be treated as academic malpractice. There is no specific style guide that must be employed when referencing, but consistent usage is expected to be applied throughout the report. Any works that have influenced the candidate's thinking but have not been cited directly in the report can be included in a separate list (i.e. 'works consulted').

Note: The candidate must include their IB candidate code and word count at the start of the report. There is no restriction on page numbers and no requirement to include a cover page or contents page.